# ST-5 GMSEC Approach
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# Goals, Objectives, Benefits

- Goals for ST-5 ground technology are
  - First mission to run with complete GMSEC suite
  - Build cost-effective model-based operations capability
- Derived benefits are as follows:
  - GMSEC suite of tools enables plug-and-play capability for rapid MOC assembly
  - GMSEC enables cost-effective model-based operations
  - Model-based operations enables lights-out autonomous operations of a constellation

# ST-5 Defining Level-1 Requirements

## Research-Quality Spacecraft

"The ST5 project shall demonstrate the ability to achieve accurate, research-quality scientific measurements utilizing a nanosatellite with a mass less than 25 kg."

## Micro-Satellite Design and Build

"The ST5 Project shall design, develop, integrate, test and operate three full service spacecraft, each with a mass less than 25kg, through the use of breakthrough technologies."

## Constellation Mission

"The ST5 project shall execute the design, development, test and operation of multiple spacecraft to act as a single constellation rather than as individual elements."
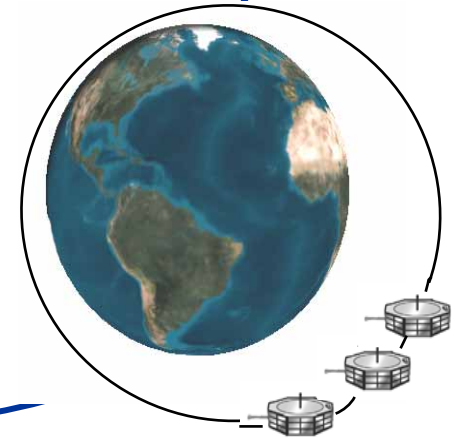
# History of Model-based Ops

- 1987 ESP – time varying limits for GRO; Shendock, Mandl, Carlton
  - More closely monitored telemetry alerts over orbit's worth of data and identified failure trends
- Mid- 1990's Altair – Model-based operations approach for MAP; Coyle, Shendock
  - State model to monitor health and safety of MAP
  - All encompassing approach expensive to build & maintain
- 2004-2006 – Self updating model-based operations on ST-5 constellation; Shendock, Mandl
  - Cost effective model to monitor health and safety
  - Model is self-tuning (can update self via telemetry)
  - Use GMSEC architecture for data and action messages
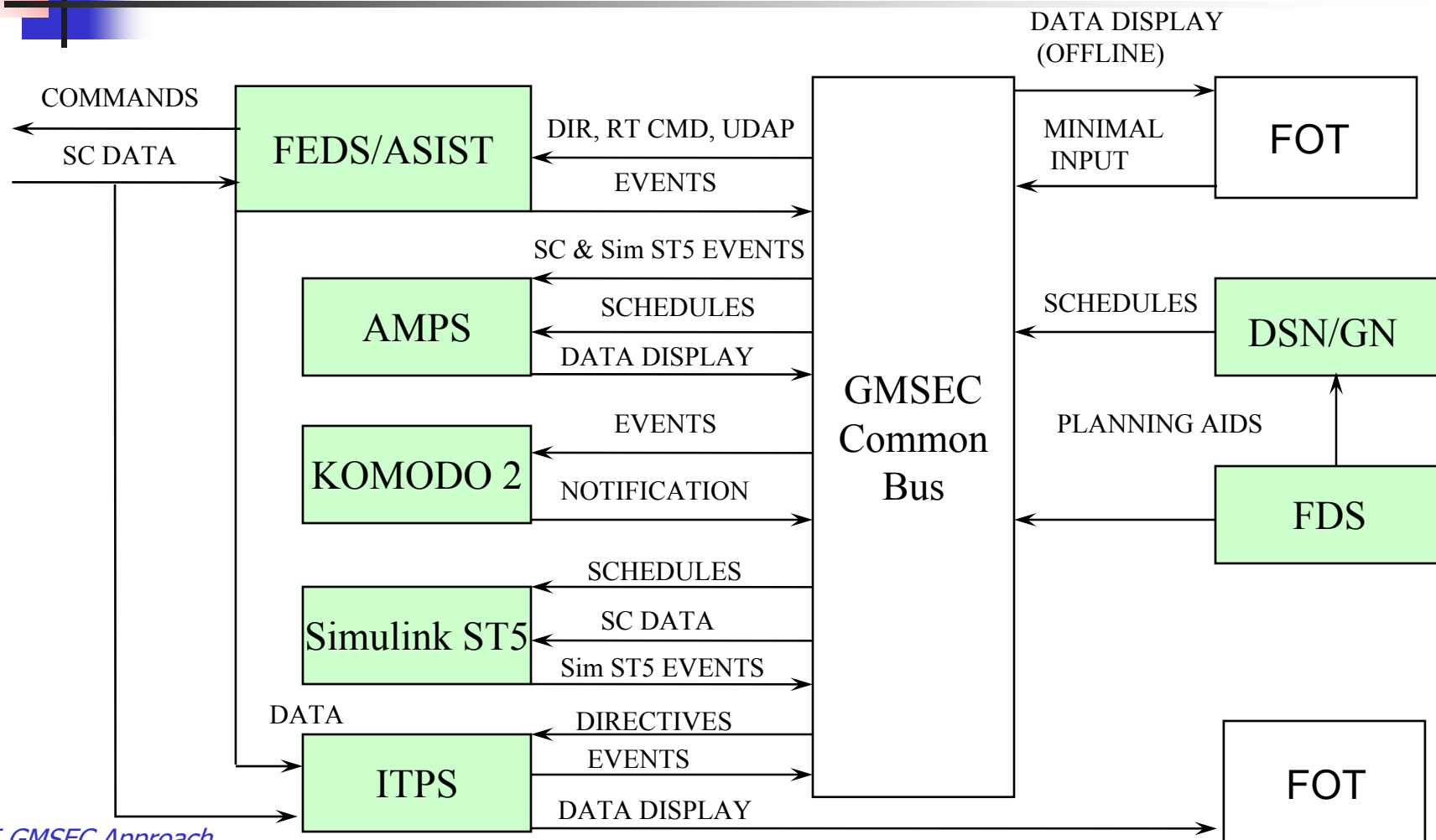
# Key Points of Model-based Operations

- Spacecraft component/subsystems models capture **relevant** aspects of their behavior
    - Use of design phase models maximized
    - Build bottom up only for components that will impact operations versus a top-down approach such as Altair
- Reasoning algorithms combine component/subsystem models to create a model of the system-wide interactions and behavior relevant to Mission Requirements.
- Reasoning engine generates the appropriate response to the current situation
    - Evaluates short-term model-generated performance profiles derived using:
        - Current state data
        - Planned command activities
    - This is different than requiring engineers to envision all possible interactions and failures at design time or perform analysis during the mission
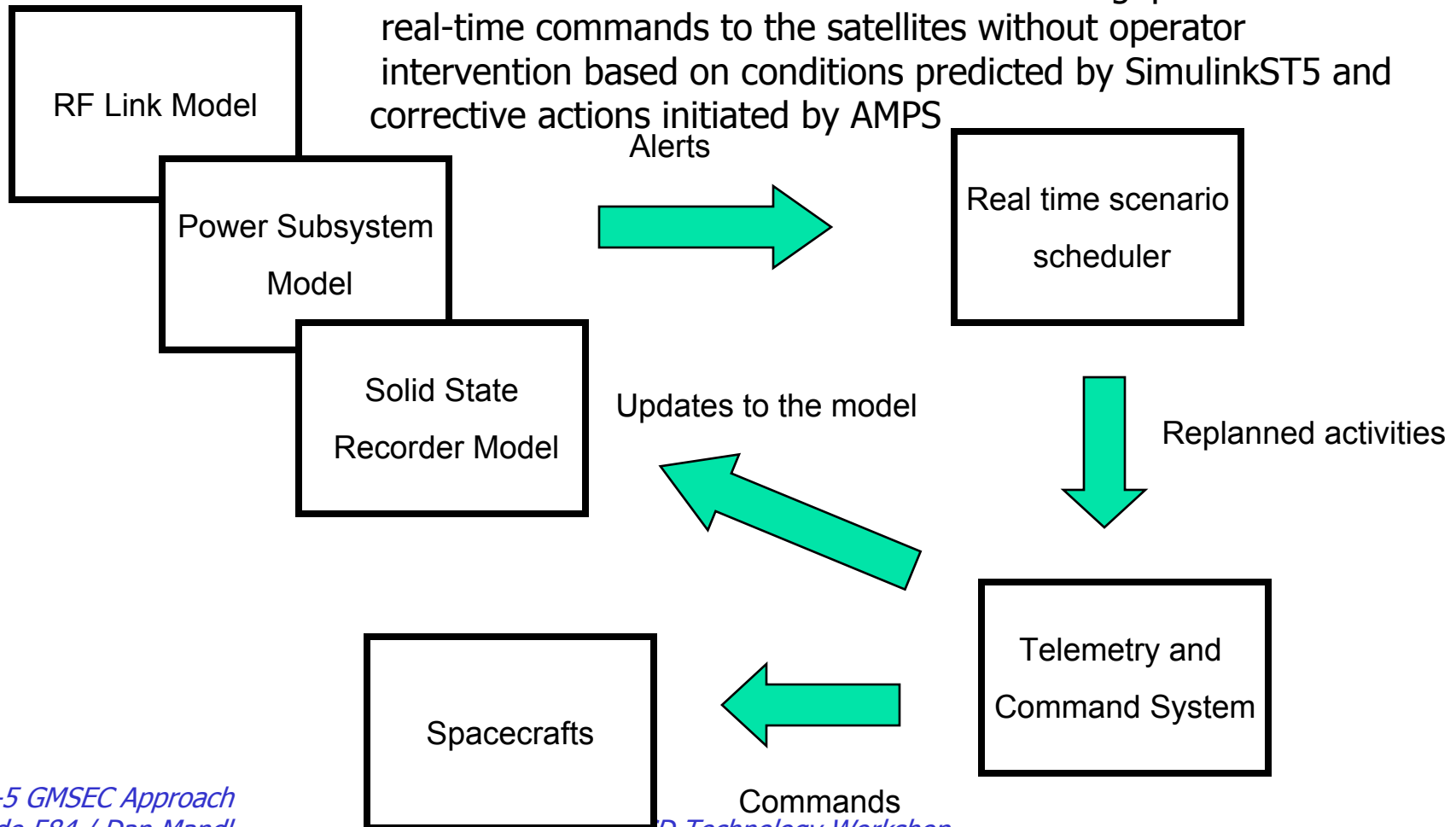
# Key Points of Model-based Operations

- The "plug-and-play" nature of the models enables low cost development of autonomy for multiple subsystems thus creating easy scalability

- Our plan is to implement models for the solid state recorder, RF link and power – constrained resources for the ST-5 mission

# ST-5 MOC GMSEC Architecture to Enable Model-based Ops

DATA DISPLAY (OFFLINE)

COMMANDS

SC DATA

**FEDS/ASIST**

DIR, RT CMD, UDAP

EVENTS

MINIMAL INPUT

**FOT**

SC & Sim ST5 EVENTS

**AMPS**

SCHEDULES

DATA DISPLAY

SCHEDULES

**DSN/GN**

**GMSEC Common Bus**

EVENTS

**KOMODO 2**

NOTIFICATION

PLANNING AIDS

**FDS**

SCHEDULES

**Simulink ST5**

SC DATA

Sim ST5 EVENTS

DATA

DIRECTIVES

**ITPS**

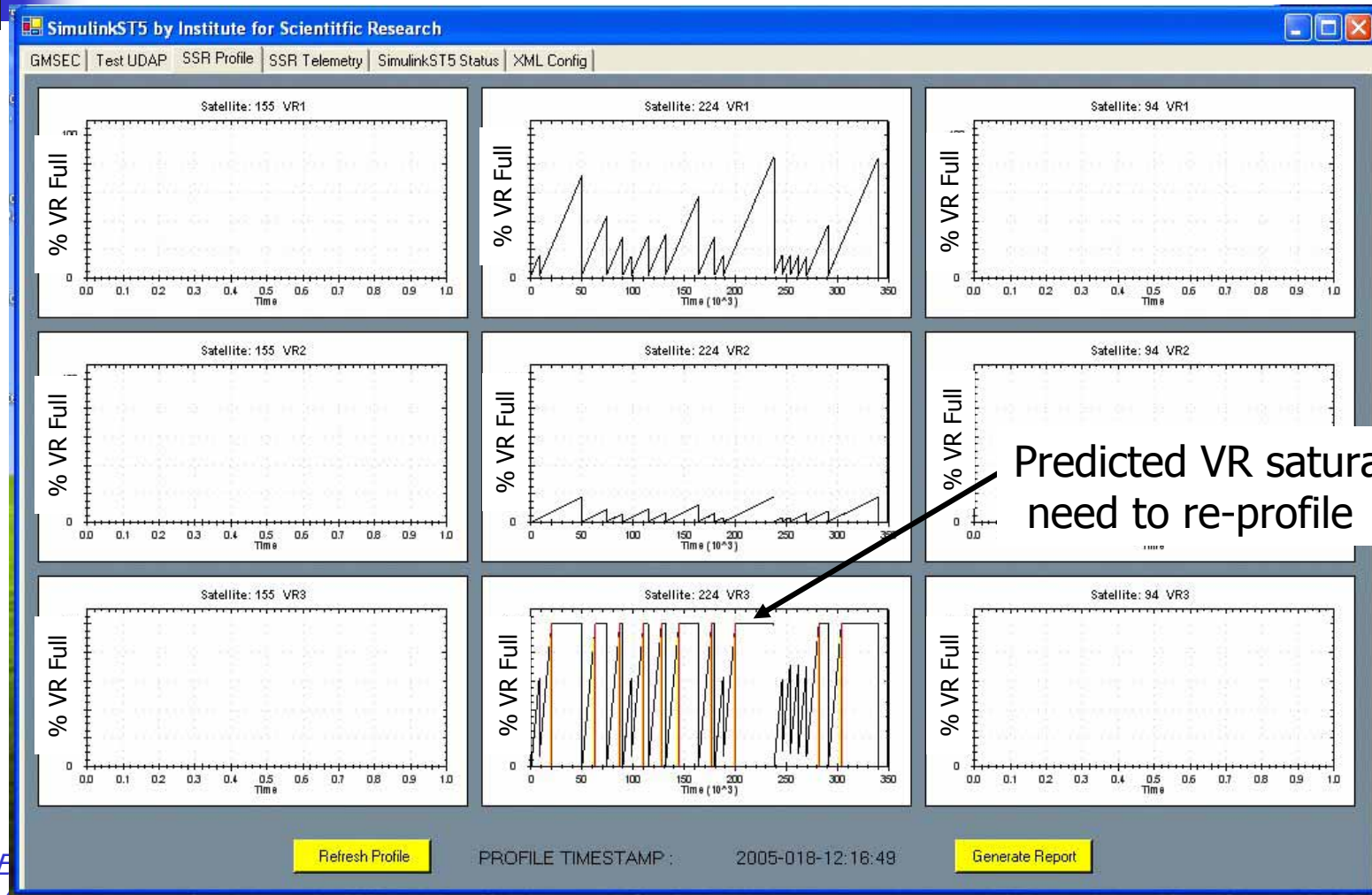EVENTS

DATA DISPLAY

**FOT**

# ST-5 Lights-out, Model-based Operations Approach with Self-Updating Feature

Note: ST-5 will be first GSFC mission to throughput real-time commands to the satellites without operator intervention based on conditions predicted by SimulinkST5 and corrective actions initiated by AMPS
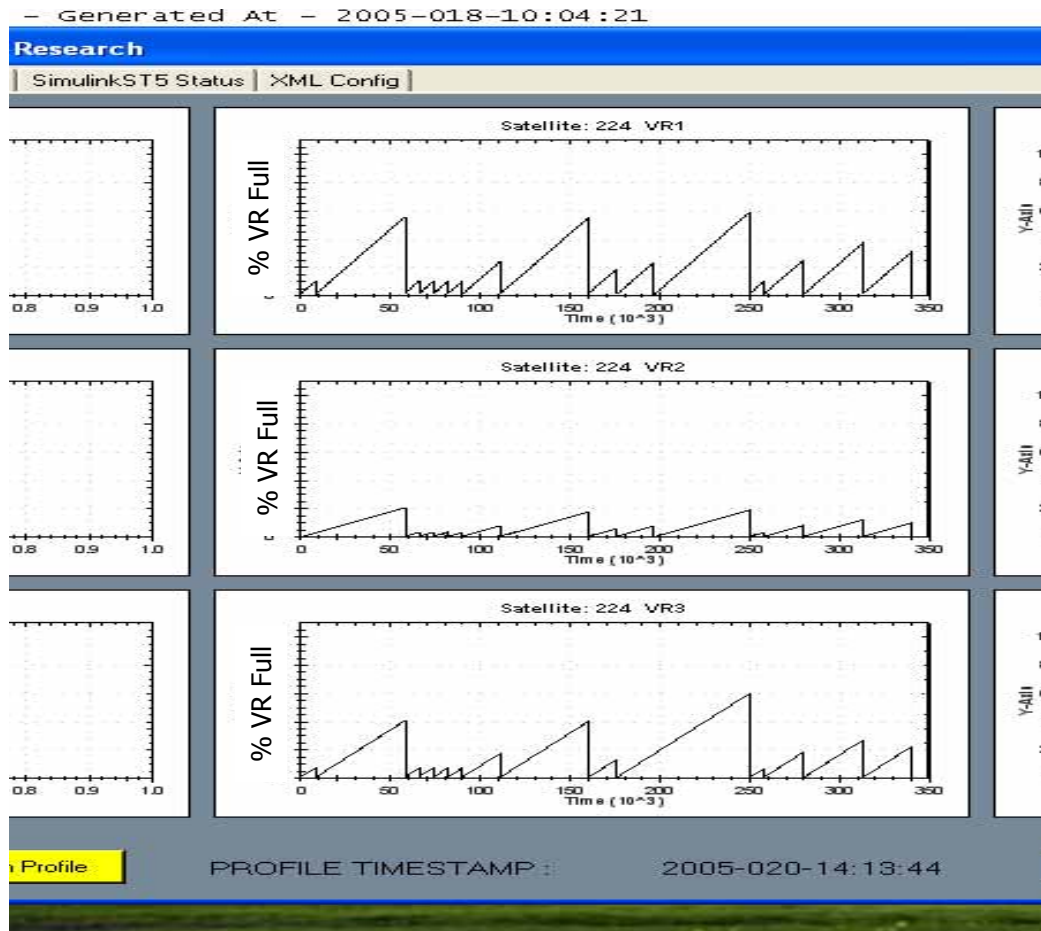
RF Link Model

Power Subsystem Model

Solid State Recorder Model

Alerts →

Real time scenario scheduler

↓ Replanned activities

Updates to the model ←

Telemetry and Command System

Spacecrafts

← Commands

# SSR Model Profile Display Showing SC 224 FlatSat Data with VR3 Violations



Predicted VR saturation, need to re-profile

# SSR Model Profile After Commands Issued to FlatSat to Repartition SSR



- Re-profile command was issued to eliminate future VR violations (i.e. early saturation of VR capacity)
- New profile for VR's in question displayed showing that no VR saturations predicted with new profile

# Highlights of Model to Manage RF Link

- Each ST-5 spacecraft has 2 omni antennas transmitting simultaneously, creates zone of self interference called "zone of interference (ZOI)"

  - Downlink data quality is a function of S/C to station geometry, attitude error angle, and transmit power profile
    - Geometry considerations are modeled using IIRV input
    - Attitude error is obtained from MOC data
    - Transmit power profile is tuned using SimulinkST5 algorithms to analyze ground station monitor data

  - Model will maintain the transmit power profile while on-orbit and use this to very precisely determine ZOI times for distribution to the DSN & GN
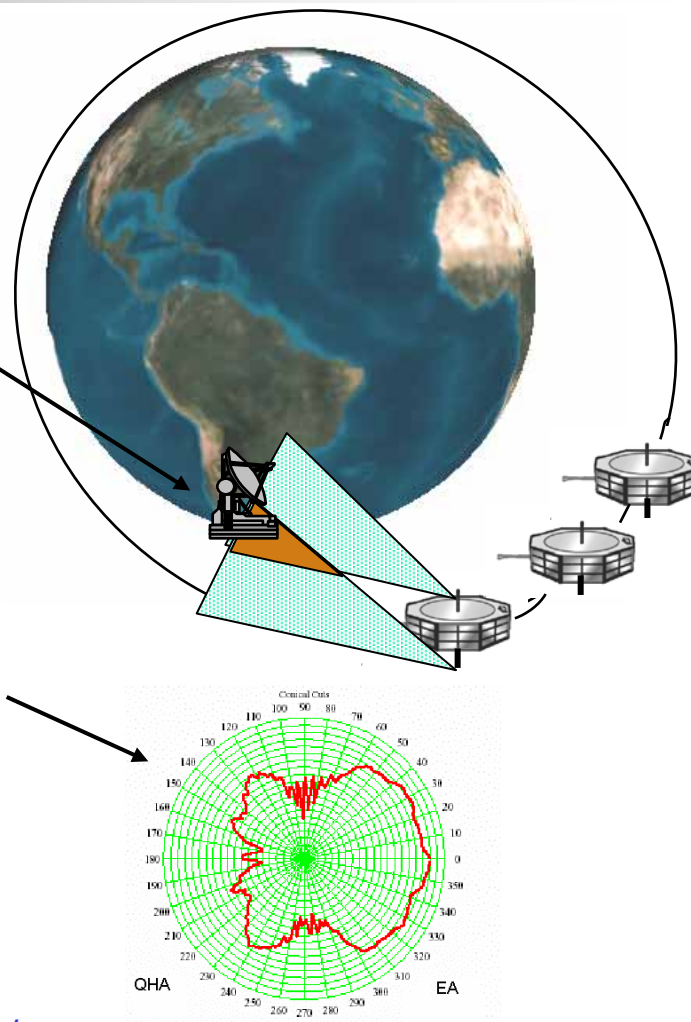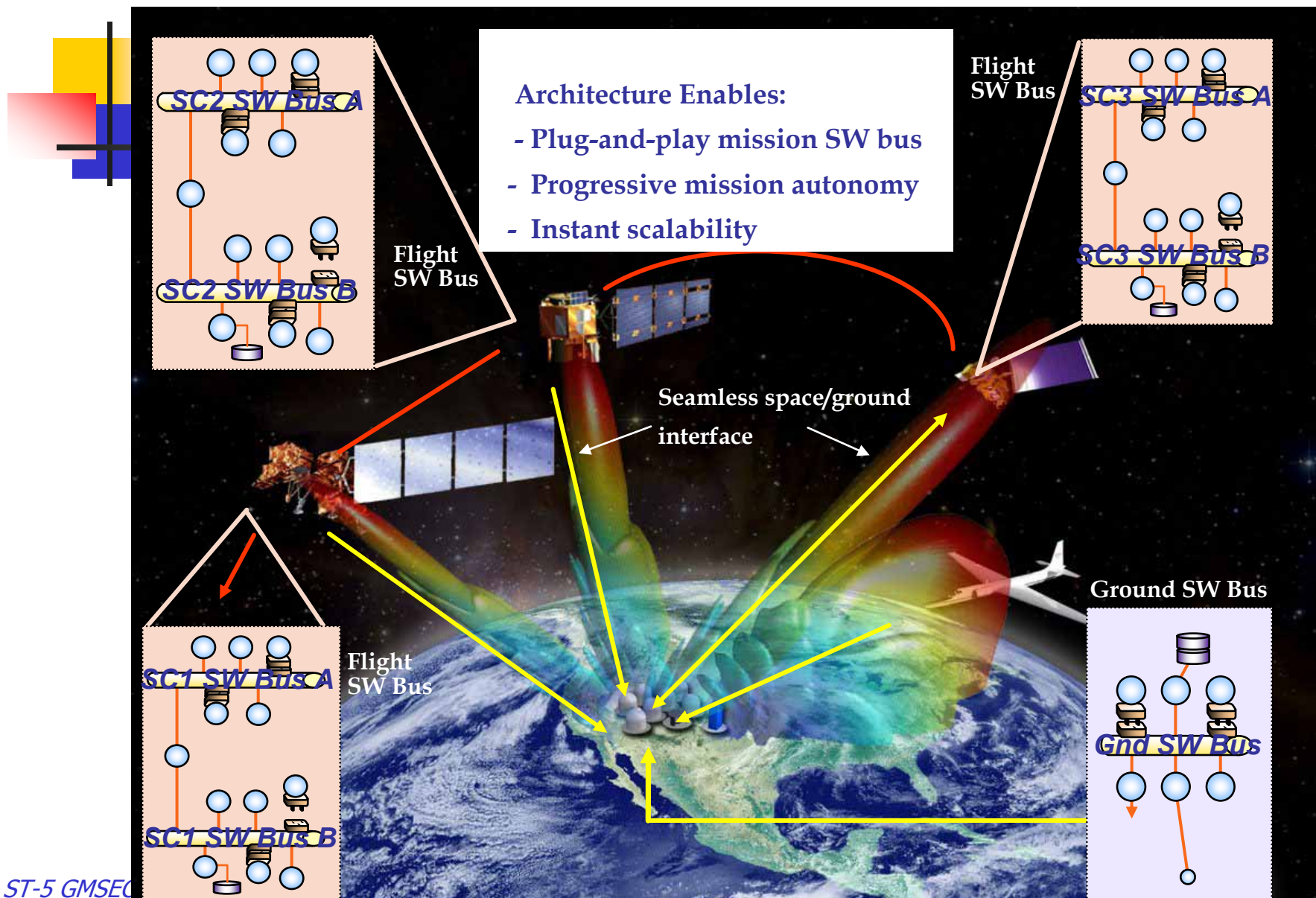
# Highlights of Power Model

- Utilize orbit related data generated by the model
- Integrate the existing Simulink Power model developed during ST-5 power system design
- Power system performance parameters are tuned using SimulinkST5 algorithms to analyze spacecraft data
- Model will be used to:
  - Generate long-term profiles based on proposed activity plan to support off-line mission planning
  - Provide short-term profiles using current state from telemetry and committed activity plan to assess power system state of health
- Use model issues alerts to AMPS for necessary action in response to profiled excessive depth of discharge

# Extending the Concept End-to End for Future Missions



**SC2 SW Bus A**

**SC2 SW Bus B**

**SC1 SW Bus A**

**SC1 SW Bus B**

**SC3 SW Bus A**

**SC3 SW Bus B**

**Gnd SW Bus**

Flight SW Bus

Flight SW Bus

Flight SW Bus

Flight SW Bus

Ground SW Bus

**Architecture Enables:**

- Plug-and-play mission SW bus

- Progressive mission autonomy

- Instant scalability

Seamless space/ground interface

# Other Future Implications

- Build future satellites and integrate into missions more efficiently by:
    - Use constellation-ready, GMSEC compatible Simulink bus to integrate proposed models
    - Build mission model (e.g. determine what models add value) – performed by mission system & operations engineers
    - Integrate component models (e.g. collect and evaluate design phase models) - performed by system engineers for box
    - Perform I&T by integrating models of how I&T is supposed to work – performed by I&T test conductors (issue exists as to value of this step)
    - Fine tune models pre-launch and post launch manually at first and then automatically to enable progressive mission autonomy – performed by operations, mission systems and box system engineers
    - Models stored in library for future mission re-use